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(54) **A METHOD FOR MONITORING THE HEALTH OF A PATIENT BY MEASURING AND PREDICTING THE GLUCOSE LEVEL OF THE PATIENT'S BLOOD SAMPLE**

VERFAHREN ZUM ÜBERWACHEN DER GESUNDHEIT EINES PATIENTEN DURCH MESSEN UND VORHERSAGE DES GLUCOSESPIEGELS EINER BLUTPROBE DES PATIENTEN

PROCEDE DE SURVEILLANCE DE LA SANTE D'UN PATIENT, PAR MESURE ET PREDICTION DES TAUX DE GLUCOSE DE L'ECHANTILLON SANGUIN DU PATIENT

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(56) References cited:
DE-A- 4 221 848 **US-A- 4 871 351**
US-A- 5 251 126

- **PROCEEDINGS OF THE ANNUAL INTERNATIONAL CONFERENCE OF THE IEEE ENGINEERING IN MEDICINE AND BIOLOGY SOCIETY, Vol. 14, November 1992, (PARIS, FRANCE), pages 1238-1239, E.J. GOMEZ et al., "A Telemedicine Distributed Decision-Support System for Diabetes Management".**

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Description

FIELD OF THE INVENTION

[0001] The present invention relates to a method for monitoring the health of a patient, wherein the glucose level of the patient's blood sample is measured. The invention also relates to a monitoring equipment for monitoring the health of a patient, the equipment comprising means for receiving a measurement result indicating the glucose level in the patient's blood sample and for storing it in a first memory means together with data indicating the moment of the measurement.

DESCRIPTION OF THE PRIOR ART

[0002] As is well known, monitoring the health of a patient with diabetes is primarily based on the measurement of the patient's blood glucose level at regular intervals. Treating diabetes requires regular measurements and regular monitoring of the measurement results in order to ensure that the patient's blood glucose level definitely remains within the allowable area and that the patient's medication is optimal.

[0003] In the present health care system it is not possible for financial and practical reasons for a person specialized in treating diabetes to personally monitor continuously the health of a patient, but the monitoring of the patient's health is largely dependent of the patient himself. Therefore the patient himself must perform measurements at regular intervals, even as often as 6 to 8 times a day. In order that the doctor treating the patient could obtain data about the development of the patient's health over a longer period, the patient must also keep a record of the measurement results, which the doctor can examine afterwards.

[0004] The fact that a relatively large number of patients with diabetes also contract a secondary disease (e.g. cardiovascular diseases, neuropathy or blindness), which in turn causes considerable costs for the society, clearly indicates that at the moment doctors cannot treat patients with diabetes sufficiently effectively or cannot help the patients to care for themselves. One reason for this is that each doctor often treats a high number of patients, whereupon the contact between each individual patient and the doctor is insufficient and the doctor cannot therefore monitor the development of the health of individual patients sufficiently effectively.

[0005] Document DE-A-4221848 discloses the method of calibrating an intracorporeal glucose measuring device such as an implanted enzymatic glucose electrode. A reference module is used to generate a predicted glucose value using a model of the biological system. The input parameters required for this model are nutrition, insulin and physical load parameters. The reference module is initialized using an initialisation module. The predicted glucose level is compared with the glucose level measured by the intracorporeal measuring device and the result of the comparison is used, in an adaption module, to calibrate the measuring device. The described model used to calculate the predicted glucose model is fixed following the initialisation.

SUMMARY OF THE INVENTION

[0006] The purpose of the present invention is to facilitate and improve the treatment of a patient with diabetes and to provide a method by means of which the patient is able to care for himself more effectively than previously. This object is achieved with a method according to the invention, characterized by the method comprising

formulating an adaptive mathematical model ($\underline{H}$) about the behaviour of the patient's blood glucose level, the model taking into account at least the patient's diet, medication and physical strain and comprising comparing predictive values $\hat{g}(t_i)$, provided by the model, to measured glucose levels $g(t_i)$ and correcting the mathematical model ($\underline{H}$) on the basis of the result of said comparison, and

providing the patient with means for utilizing said mathematical model ($\underline{H}$), so that the patient can himself monitor and predict the effect of the treatment he is to follow on the behaviour of his blood glucose level.

[0007] Another purpose of the invention is to provide a monitoring equipment which facilitates and improves the treatment of a patient. This object is achieved with a monitoring equipment according to the invention, characterized in that the equipment comprising

means (15, 15') for receiving a measurement result indicating the glucose level in the patient's blood sample and for storing it in a first memory means (10, 10') together with data indicating the moment of the measurement, wherein the monitoring equipment comprises means (15, 15') for receiving data concerning at least the patient's diet, medication and physical strain and for storing the data in the first memory means (10, 10'),

data processing means (11, 12, 11', 12') for calculating a predictive value $\hat{g}(t_i)$ on the basis of the data stored in the first memory means (10, 10'), the predictive value indicating the patient's predicted blood glucose level at a predetermined moment, and

corrector means (13, 13') for calculating the difference between the calculated predictive value $\hat{g}(t_i)$ and the patient's actual blood glucose level $g(t_i)$ calculated at said predetermined moment, and for correcting the mathematical model utilized by the data processing means (11, 12, 11', 12') to calculate a predictive value in order to take into account said difference in the subsequent calculations of predic-

tive values.

[0008] The invention is based on the id a that when an adaptive mathematical modes is formulated concerning the behaviour of a patient's blood glucose level and when the patient is provided with a monitoring equipment comprising data processing means for calculating a predictive value describing the patient's blood glucose level on the basis of data supplied to the equipment, and corrector means for correcting the model used for calculating the predictive value on the basis of the difference between the previous predictive values and the actual measurement results, the patient can take care of himself better than before and monitor and predict the development of his own health, since he is able to better estimate, by means of the monitoring equipment, how his blood glucose level is likely to change on the basis of the predictable medication, diet and physical strain. In other words, if the predictive value turns out to be bad, the patient can contact for example his doctor in order to discuss possible changes in medication or he can alternatively change his diet, for instance.

[0009] Due to the corrector means the monitoring equipment becomes adaptive, i.e. it can take into account the characteristic features of the patient in question in the mathematical model utlilized by the data processing means, so that the differences between the previous predictive values and the actual measurement results can be used in the long term to develop a mathematical model for the patient in question. If the mathematical model used for calculating a predictive value turns out to be very accurate in the long term due to the action of the corrector means, i.e. if the difference between the predictive value and the actual value measured afterwards is close to zero, the patient can even skip some measurements due to the monitoring equipment according to the invention, since he can accurately predict with the equipment the development of the glucose level by means of the expected diet, medication and physical strain. This considerably facilitates the situation for the patient since the blood glucose level is rather complicated to measure.

[0010] The method and the monitoring equipment according to the invention therefore have the following primary advantages. The method and the monitoring equipment considerably improve and facilitate the patient's self-care since the patient can estimate the development of his blood glucose level better than before. The doctor obtains more detailed and more accurate data about the patient's health since it is possible to read from the memory of the monitoring equipment data that the doctor can utilize later for example for a trend analysis. Due to the monitoring equipment, the number of the daily glucose level measurements can be decreased in the long term.

[0011] In a preferred embodiment of the monitoring equipment according to the invention, th monitoring equipment consists of a data proc ssing equipment of a hospital or the like with which the patient communicates via a communications device utilizing wireless data transmission. This embodiment of the invention makes it possible for the patient to transmit the required data to the monitoring equipment regardless of his current location. This embodiment also enables for the doctor to monitor, if desired, the most recent data concerning the patient's health without a need for an appointment, or even a phone call, between the patient and the doctor.

[0012] In another preferred embodiment of the monitoring equipment according to the invention, the monitoring equipment and the measuring equipment suitable for measuring the blood glucose level are integrated into a communications device, preferably a mobile phone, utilizing wireless data transmission. This embodiment of the invention frees the patient from carrying with him several separate conspicuous devices, since only one device is sufficient. Also in this embodiment the patient can continuously transmit, via the communications device, data concerning his health to the doctor treating him, regardless of the patients location, and the doctor can monitor the development in the patient's health and even contact the patient directly by means of the mobile phone, if required. In this embodiment, the calculation of the predictive value is naturally not dependent on whether the patient is located in a shadow area of the mobile system at the moment, since the calculation of the predictive value takes place entirely in the monitoring equipment the patient carries with him. If the patient is in a shadow area at the moment of calculation, he can transmit afterwards, if he so wishes, the data that he has supplied to the monitoring equipment and that has been stored in the memory thereof to the data processing system available to the doctor treating him.

[0013] The preferred embodiments of the monitoring equipment according to the invention are disclosed in the appended dependent claims 3 to 7.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] In the following, the invention will be described in greater detail, by way of an example, by means of a few preferred embodiments of the invention illustrated in the accompanying figures, in which

Figure 1 illustrates the first preferred embodiment of the monitoring equipment according to the invention,

Figures 2 and 3 illustrate the second preferred embodiment of the monitoring equipment according to the invention, and

Figure 4 illustrates the calculation of a predictive value.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0015] Figure 1 illustrates the first preferred embodiment of the monitoring equipment according to the invention. In the case shown in Figure 1, the monitoring equipment consists of a hospital data processing system 9 and the applications software used therein.

[0016] In the situation shown in Figure 1, the patient can use a mobile phone 1 by means of which he can supply data to the monitoring equipment 9. When the patient wants the monitoring equipment 9 to calculate a predictive value for the likely blood glucose level at a certain moment, for example after five hours, he supplies data concerning at least the most recent measurement result and the time of the measurement (if the data concerning the measurement result has not been supplied before to the monitoring equipment), the expected medication, diet, physical strain and the moment for which the predictive value is to be calculated (i.e. in this example five hours later) to the monitoring equipment 9 via the keyboard of the mobile phone 1. If the mobile phone comprises an integrated measuring device for measuring the glucose level, the measurement result or the time of the measurement do not have to be supplied since they may be stored in the memory of the mobile phone 1. The mobile phone 1 that is assumed to be, by way of an example, a mobile phone of the GSM mobile system (Groupe Spécial Mobile) then transmits the supplied data in the form of a short message 3 to a base station 4. The base station 4 forwards the message via a base station controller 5, a mobile services switching centre (MSC) 6 and a gateway centre 7 to a short message service centre (SMSC) 8 in the mobile system. The GSM system and the short message service thereof are described in greater detail for example in *The GSM System for Mobile Communications* by M. Mouly and M.-B. Pautet, Palaiseau, France, 1992, ISBN: 2-9507190-0-7, and therefore they will not be described in greater detail in this connection.

[0017] The short message service centre 8 is programmed to transmit the short message received from the patient's mobile phone 1 directly to the data processing system 9 of the hospital. Therefore the doctor treating the patient has at all times access to the most recent data concerning the patient, regardless of the patient's current location.

[0018] When the monitoring equipment 9 has received, via its transceiver unit 15, the data supplied by the patient, it stores it in a first memory means 10 that may consist of, for example, a file in the hard disk of a computer. A calculator 12 thereafter starts calculating a predictive value on the basis of the data stored in the first memory means. During the calculation, the calculator 12 also takes into account correction coefficients stored in a second memory means 11. The first 10 and the second 11 memory means may consist of, for example, separate storage locations situated physically in the sam memory chip, or altematively of separate files located in the same computer hard disk. Th calculation of a predictive value is described in greater detail in connection with Figure 3.

[0019] When the predictive value has been calculated, the monitoring equipment 9 transmits it in the form of a short message to the patient's mobile phone 1, and the patient can ensure by means of the predictive value that his blood glucose level remains within the allowable area for the next five hours. On the other hand, if the predictive value shows that the blood glucose level is likely to change unfavourably during the following, for example five, hours, the patient may consider changing his diet, physical strain or even medication and he can supply the new changed data to the monitoring equipment and obtain a new predictive value which indicates the effect of the change on the blood glucose level.

[0020] Next time when the patient measures the blood glucose level and supplies the data concerning the measurement value and the moment of measurement to the monitoring equipment 9, the equipment stores this data into the first memory means 10 and also uses this data for correcting the mathematical model used for calculating the predictive value.

[0021] If the most recent moment of measurement corresponds to the moment for which the calculator 12 has already previously calculated a predictive value, the calculator 12 retrieves from the memory 1 this value and supplies it to the corrector 13. The corrector 13 thereafter calculates the difference between the predictive value and the measurement value. On the basis of this difference, the corrector 13 changes the correction coefficients used for calculating the predictive value in such a way that if the calculator would calculate a new predictive value with the same initial values stored in the memory means 10 but with the new correction coefficients, the difference between the predictive value and the measured value would be smaller than before. The new correction coefficients are stored in the second memory means 11 from which the calculator 12 retrieves them for the next calculation of a predictive value.

[0022] If the most recent moment of measurement does not correspond to the moment for which the calculator 12 has already before calculated a predictive value, the calculator 12 first calculates a new predictive value for this moment of measurement on the basis of the data stored in the memory means 10. The corrector 13 thereafter calculates the difference between the predictive value and the measurement value and new correction coefficients in the above-described manner.

[0023] If the difference between the measurement value and the predictive value calculated for example for a certain time of day is repeatedly very close to zero in the long term (for several weeks), the monitoring equipment 9 may find that the predictive value is sufficiently accurate for the time of day. In such a case, th monitoring equipment 9 may suggest to th patient for xampl with a short message that ther is no need to

measure the blood glucose level at the aforementioned moment. Th refore, the patient can decrease th number of th daily measur ments one at a time as the mathematical model proves to be sufficiently accurate, until a few as 1 or 2 measurements are required each day. This considerably facilitates the patient's daily life compared to the 6 to 8 daily measurements required at present for achieving a balance.

[0024] Figures 2 and 3 illustrate the second preferred embodiment of the monitoring equipment according to the invention. In the case shown in Figures 2 and 3, the monitoring equipment 9' is connected to a mobile phone.

[0025] The mobile phone MS may be for example a conventional GSM mobile phone the battery space of which comprises, instead of a conventional battery, a unit 14' which contains integrated both a battery and components required for calculating a predictive value, these components including for example a calculator 12', a corrector 13' and memory means 10' and 11'. Since the unit 14' is connected to a communication bus of the mobile phone MS, it is possible to supply data required for calculating a predictive value to the calculator 12' by means of the keyboard 15' of the mobile phone. Correspondingly, the calculator 12'may forward the calculated predictive value to the user via the display 16' of the mobile phone. Therefore, the calculation of a predictive value does not require communication with a separate data processing equipment, but the monitoring equipment 9' can independently calculate a predictive value on the basis of the data supplied thereto. However, if the patient desires ha can also transmit the data he supplied to the monitoring equipment, including the latest measurement results, to the data processing system available to the doctor treating him by means of a short message.

[0026] The unit 14' preferably also comprises an integrated measuring device (not shown in the figures) known per se for measuring the glucose level of a blood sample. Therefore, the patient does not have to carry with him several separate instruments, but the mobile phone/monitoring equipment alone is sufficient.

[0027] Figure 4 illustrates the calculation of a predictive value. According to the invention, the calculation of a predictive value can utilize any adaptive mathematical model known per se, wherein the difference between the calculated predictive value and the actual measurement result can be used for correcting the mathematical model in such a way that the difference between the caluculated predictive values and the actual measurement results will be minimized in the long term. In other words, the mathematical model is able to "learn" how the patient's sysem, i.e. the blood glucose level, varies when certain initial values are changed. An example of a mathematical model known per se that can be utilized in the monitoring equipment according to the invention is a so-called Widrow's adaptive LMS (Least Means Square) algorithm.

[0028] In figur 4, basic data $\underline{X}$ which may include data about the moment t_i for which th predictive value is to be calculated, the latest measurement result, the moment of measurement, and the estimated medication, diet and physical strain of the patient is supplied to the mathematical model H. The mathematical model of Figure 4 utilizes the fact that the blood glucose level of a person with diabetes usually follows a certain daily pattern with a certain accuracy, i.e. the glucose level follows the daily routine of the diabetic approximately in the same manner from one day to another. Therefore, the effect of different initial values on the glucose level can be monitored in the long term by keeping a record of the initial values and the actual measurement values. The mathematical model can therefore be amended in such a way that the model provides a more accurat predictive value. In practice, this may take place for example in such a manner that for each moment in the daily routine there is a separate correction table wherein each initial value has its own correction coefficient, i.e. for example a weighting coefficient, which is utilized when calculating a predictive value and the value of which is changed when the real difference between the caluclated predictive value and the actual measurement value is known.

[0029] In the situation shown in Figure 4, a predictive value for the moment t_i can be calculated for example from the formula $\hat{g}(t_i) = \underline{H} * \underline{X}$. The calculated predictive value is thereafter stored in the memory until the actual measurement value for the patient at the moment t_i is obtained. When the actual measurement value $g(t_i)$ is known, the difference between the predictive value and the measurement value is calculated, i.e. $e(t_i) = g(t_i) - \hat{g}(t_i)$. The difference is utilized for correcting the mathematical model $\underline{H}$, for example in such a way that the correction coefficients used in the model are corrected by means of the formula $h_{ik+1} = h_{ik} + 2 * \mu * e(t_i) * x_i(t_i)$, wherein h_{ik} is the weighting coefficient of the initial value x_i used in the calculation at the moment t_i, and μ is a small positive constant which ensures that the model does not change radically on the basis of one single calculation, but its coefficients change with relatively small steps towards optimal values.

[0030] It should be understood that the above description and the related figures are only intended to illustrate the present invention. Different variations and modifications of the invention will be evident for those skilled in the art without departing from the scope of the invention disclosed in the appended claims.

Claims

1. A method of predicting the glucose level $g(t_i)$ in a patient's blood comprising:

   formulating an adaptive mathematical model ($\underline{H}$) about the behaviour of the patient's blood glucos l v l, the model taking into account at least the patient's di t, medication and physical

strain and comprising comparing predictive values $g(t_i)$, provided by the model, to measured glucose levels $g(t_i)$ and correcting the mathematical model (H) on the basis of the result of said comparison, and
providing the patient with means for utilizing said mathematical model (H), so that the patient can himself monitor and predict the effect of the treatment he is to follow on the behaviour of his blood glucose level.

2. Monitoring equipment for predicting the glucose level in a patient's blood comprising:

   means (15, 15') for receiving a measurement result indicating the glucose level in the patient's blood sample and for storing it in a first memory means (10, 10') together with data indicating the moment of the measurement, wherein the monitoring equipment comprises means (15, 15') for receiving data concerning at least the patient's diet, medication and physical strain and for storing the data in the first memory means (10, 10'),
   data processing means (11, 12, 11', 12') for calculating a predictive value $\hat{g}(t_i)$ on the basis of the data stored in the first memory means (10, 10'), the predictive value indicating the patient's predicted blood glucose level at a predetermined moment, and
   corrector means (13, 13') for calculating the difference between the calculated predictive value $\hat{g}(t_i)$ and the patient's actual blood glucose level $g(t_i)$ calculated at said predetermined moment, and for correcting the mathematical model utilized by the data processing means (11, 12, 11', 12') to calculate a predictive value in order to take into account said difference in the subsequent calculations of predictive values.

3. Monitoring equipment according to claim 2, **characterized by**

   the data processing means comprising a second memory means (11, 11') for maintaining correction coefficients utilized in the calculation of a predictive value, the data processing means (12, 12') being arranged to search from the second memory means (11, 11') the correction coefficients corresponding to the data stored in the first memory means (10, 10'), and to utilize said correction coefficients in the calculation of a predictive value, and
   the corrector means (13, 13') being arranged to change the value of the correction coefficients used in the calculation in order to minimize the difference b tw en th predictive value $\hat{g}(t_i)$ and the glucos level $g(t_i)$ measured at said predetermined mom nt, and to store said changed correction co ffici nts in th second memory means (11, 11').

4. Monitoring equipment according to claim 2 or 3, **characterized by** said means for receiving data (15, 15'), said data processing means (11, 12, 11', 12'), and said corrector means (13, 13') being provided by a data processing system (9) of a hospital, a health care centre or the like, wherein the equipment further comprises a communication device (1) that is available to the patient and that utilizes a wireless data transmission link, and the means (15) for receiving data concerning the measurement result, moment of measurement, diet, medication and physical strain comprising means for receiving said data from said communication device (1), the monitoring equipment comprising transmitter means for transmitting the calculated predictive value $\hat{g}(t_i)$ to the communications device (1) available to the patient.

5. Monitoring equipment according to claim 2 or 3, **characterized by** said monitoring equipment comprising a measuring unit for measuring the glucose level of a patient's blood sample, and for storing the data indicating the moment of measurement of the first measurement result in the first memory means (10').

6. Monitoring equipment according to claim 5, **characterized by** said monitoring equipment comprising a communications device (MS) connected to the measuring unit, the communications device (MS) comprising a mobile phone of a cellular radio system or to a two-way pager, the monitoring equipment further comprising means for transmitting the data stored in the first memory means (10') via said data transmission link to a data processing system that is available to a person treating the patient.

7. Monitoring equipment according to claim 6, **characterized by** the measuring unit and the communications device constituting a combined element, wherein a battery of the mobile phone or two-way pager and the measuring unit are integrated into one component (14') that fits into the battery space of the mobile phone or two-way pager.

Patentansprüche

1. Verfahren zum Vorhersagen des Glucosespiegels $g(t_i)$ im Blut eines Patienten, mit den folgenden Schritten:

   - Formulieren eines adaptiven mathematischen Modells (H) zum Verhalt n des Blutglucose-

spiegels des Patienten, wob i das Modell zumindest di Ernährung, die Medikamentenversorgung und die körperlich Belastung des Patienten berücksichtigt und zu ihm der Vergleich von durch das Modell gelieferten Vorhersagewerten $\hat{g}(t_i)$ mit gemessenen Glucosespiegeln $g(t_i)$ und eine Korrektur des mathematischen Modells ($\underline{H}$) auf Grundlage des Vergleichsergebnisses gehören; und

- Versorgen des Patienten mit einer Einrichtung zum Ausnutzen des mathematischen Modells ($\underline{H}$), so dass der Patient selbst die Wirkung der Behandlung überwachen und vorhersagen kann, der er auf Grundlage des Verhaltens seines Blutglucosespiegels folgen soll.

2. Überwachungsanlage zum Vorhersagen des Glucosespiegels im Blut eines Patienten mit:

- einer Einrichtung (15, 15') zum Empfangen eines den Glucosespiegel in einer Blutprobe des Patienten anzeigenden Messergebnisses und zum Einspeichern desselben in eine erste Speichereinrichtung (10, 10') gemeinsam mit den Messzeitpunkt anzeigenden Daten, wobei die Überwachungsanlage eine Einrichtung (15, 15') zum Empfangen von Daten betreffend zumindest die Ernährung, die Medikamentenversorgung und die körperliche Belastung des Patienten und zum Einspeichern der Daten in die erste Speichereinrichtung (10, 10') aufweist;
- einer Datenverarbeitungseinrichtung (11, 12, 11', 12') zum Berechnen eines Vorhersagewerts $\hat{g}(t_i)$ auf Grundlage der in der ersten Speichereinrichtung (10, 10') abgespeicherten Daten, wobei der Vorhersagewert den vorhergesagten Blutglucosespiegel des Patienten zu einem vorbestimmen Zeitpunkt anzeigt; und
- einer Korrektureinrichtung (13, 13') zum Berechnen der Differenz zwischen dem berechneten Vorhersagewert $\hat{g}(t_i)$ und dem zum vorbestimmten Zeitpunkt gemessenen tatsächlichen Blutglucosespiegel $g(t_i)$ des Patienten sowie zum Korrigieren des von der Datenverarbeitungseinrichtung (11, 12, 11', 12') zum Berechnen eines Vorhersagewerts genutzten mathematischen Modells, um die Differenz bei folgenden Berechnungen von Vorhersagewerten zu berücksichtigen.

3. Überwachungsanlage nach Anspruch 2, **dadurch gekennzeichnet, dass:**

- die Datenverarbeitungseinrichtung eine zweite Speichereinrichtung (11, 11') zum Registrieren von bei der Berechnung des Vorhersagewerts benutzten Korrekturkoeffizi nt n aufweist und die Datenv rarbeitungs inrichtung (12, 12') so ausgebildet ist, dass sie aus der zw iten Sp ichereinrichtung die den in der ersten Speichereinrichtung (10, 10') gesp ich rten Daten ntsprechenden Korrekturkoeffizienten heraussucht und diese bei der Berechnung eines Vorhersagewerts verwendet; und
- die Korrektureinrichtung (13, 13') so ausgebildet ist, dass sie den Wert der bei der Berechnung verwendeten Korrekturkoeffizienten so ändert, dass die Differenz zwischen dem Vorhersagewert $\hat{g}(t_i)$ und dem zum vorbestimmten Zeitpunkt gemessenen Glucosespiegel $g(t_i)$ minimiert wird, und sie die geänderten Korrekturkoeffizienten in die zweite Speichereinrichtung (11, 11') einspeichert.

4. Überwachungsanlage nach Anspruch 2 oder 3, **dadurch gekennzeichnet, dass** die Einrichtung zum Empfangen von Daten (15, 15') die Datenverarbeitungseinrichtung (11, 12, 11', 12') und die Korrektureinrichtung (13, 13') durch ein Datenverarbeitungssystem (9) eines Krankenhauses, eines Gesundheitsfürsorgezentrums oder dergleichen gebildet ist, wobei die Anlage ferner über eine Kommunikationsvorrichtung (1) verfügt, die dem Patienten verfügbar ist und die eine datenlose Datenübertragungsstrecke nutzt, und die Einrichtung (15) zum Empfangen von das Messergebnis, den Messzeitpunkt, die Ernährung, die Medikamentenversorgung und die körperliche Belastung betreffenden Daten eine Einrichtung zum Empfangen dieser Daten von der Kommunikationsvorrichtung (1) aufweist, wobei die Überwachungsanlage eine Übertragungseinrichtung zum Übertragen des berechneten Vorhersagewerts $\hat{g}(t_i)$ an die dem Patienten verfügbare Kommunikationsvorrichtung (1) aufweist.

5. Überwachungsanlage nach Anspruch 2 oder 3, **dadurch gekennzeichnet, dass** sie eine Messeinheit zum Messen des Glucosespiegels der Blutprobe eines Patienten und zum Speichern der den Messzeitpunkt des ersten Messergebnisses anzeigenden Daten in die erste Speichereinrichtung (10') aufweist.

6. Überwachungsanlage nach Anspruch 5, **dadurch gekennzeichnet, dass** sie eine mit der Messeinheit verbundene Kommunikationsvorrichtung (MS) aufweist, die ein Mobiltelefon eines Zellenfunksystems oder ein bidirektionaler Funkrufempfänger ist, und diese Überwachungsanlage ferner eine Einrichtung zum Übertragen der in der ersten Speichereinrichtung (10') gespeicherten Daten über die Datenübertragungsstrecke an ein Datenverarbeitungssystem, das einer den Patienten behandelnden Person zugänglich ist, aufweist.

7. Überwachungsanlage nach Anspruch 6, **dadurch gekennzeichn t, dass** di Messeinheit und di Kommunikationsvorrichtung in kombiniertes Element bilden, wobei eine Batterie des Mobiltelefons oder des bidirektionalen Funkrufempfängers und die Messeinheit in eine Komponente (14') integriert sind, die in das Batteriefach des Mobiltelefons oder des bidirektionalen Funkrufempfängers passt.

Revendications

1. Procédé de prédiction du taux de glucose (t_i) dans le sang d'un patient comprenant :

   la formulation d'un modèle mathématique adaptatif (H) concernant le comportement du taux de glucose dans le sang d'un patient, le modèle prenant en compte au moins le régime alimentaire du patient, la médication et la fatigue physique et comprenant la comparaison des valeurs prédites de comparaison (t_i), créé, par le modèle, aux taux de glucose mesurés g (t_i) et la correction du modèle mathématique (H) sur la base du résultat de ladite comparaison, et

   la fourniture au patient d'un moyen d'utilisation dudit modèle mathématique (H) de telle façon que le patient peut surveiller et prédire lui-même le résultat du traitement qu'il suit sur le comportement de son taux de glucose dans le sang.

2. Equipement de surveillance destiné à prédire le taux de glucose dans le sang d'un patient comprenant :

   un moyen (15, 15') destiné à recevoir un résultat de mesure indiquant le taux de glucose dans l'échantillon du sang d'un patient et à le mettre en mémoire dans un premier moyen de mémoire (10, 10') en même temps que les données indiquant le moment de la mesure, où l'équipement de surveillance comprend un moyen (15, 15') destiné à recevoir les données concernant au moins le régime alimentaire, la médication et la fatigue physique du patient et à mettre en mémoire les données dans le premier moyen de mémoire (10, 10'),

   un moyen de traitement de données (11, 12, 11', 12') destiné à calculer une valeur prédite (t_i) sur la base des données mises en mémoire dans le premier moyen de mémoire (10, 10'), la valeur prédite indiquant le taux de glucose prédit dans le sang d'un patient à un moment prédéterminé, et

   un moyen de correction (13, 13') destiné à calculer la différence entre la valeur prédite (t_i) calculée et le taux actuel du glucose dans le sang du patient g(t_i) calculé audit moment prédéterminé, et à corriger le modèle mathématique utilisé par le moyen de traitement de données (11, 12, 11', 12') pour calculer une valeur prédite afin de prendre en compte ladite différence dans les calculs suivants des valeurs prédites.

3. Equipement de surveillance selon la revendication 2, **caractérisé par**

   le moyen de traitement des données qui comprend un second moyen de mémoire (11, 11') pour maintenir les coefficients de correction utilisés pour le calcul d'une valeur prédite, le moyen de traitement des données (12, 12') étant agencé pour rechercher d'après le second moyen de mémoire (11, 11') les coefficients de correction correspondant aux données mises en mémoire dans le premier moyen de mémoire (10, 10'), et pour utiliser lesdits coefficients de correction pour le calcul d'une valeur prédite, et

   le moyen de correction (13, 13') qui est agencé pour changer la valeur des coefficients de correction utilisés pour le calcul afin de minimiser la différence entre la valeur prédite (t_i) et le taux de glucose g(t_i) mesuré audit moment prédéterminé, et pour mettre en mémoire dans le second moyen de mémoire (11, 11') lesdits coefficients de correction modifiés.

4. Equipement de surveillance selon la revendication 2 ou 3, **caractérisé par** ledit moyen de réception des données (15, 15'), ledit moyen de traitement des données (11, 12, 11', 12'), et ledit moyen de correction (13, 13') étant pourvu d'un système de traitement des données (9) provenant d'un hôpital, d'un centre de soins de santé ou analogue, dans lequel l'équipement comprend en outre un dispositif de communication (1) qui est disponible pour le patient et qui utilise une liaison sans fil de transmission de données, et dans lequel le moyen (15) de réception des données concernant le résultat de la mesure, le moment de la mesure, le régime alimentaire, la médication et la fatigue physique comprend un moyen de réception desdites données provenant dudit dispositif de communication (1), l'équipement de surveillance comprenant un moyen de transmission pour transmettre la valeur lesdits coefficients de correction modifiés calculée (t_i) au dispositif de communication (1) disponible pour le patient.

5. Equip ment de surveillance selon la revendication 2 ou 3, **caractérisé par** ledit équipement de sur-

veillance qui comprend une unité de mesur destinée à mesurer le taux de glucose d'un échantillon de sang du patient, et à mettr en mémoire les données qui indiquent le moment de la mesure du premier résultat de mesure dans le premier moyen de mémoire (10').

6. Equipement de surveillance selon la revendication 5, **caractérisé par** ledit équipement de surveillance qui comprend un dispositif de communication (MS) connecté à l'unité de mesure, le dispositif de communication (MS) comprenant un téléphone mobile ou bien un système radio cellulaire ou bien un récepteur de poche à deux voix, l'équipement de surveillance comprenant en outre un moyen de transmission des données mises en mémoire dans le premier moyen de mémoire (10') par l'intermédiaire de ladite liaison de transmission des données à un système de traitement des données qui est disponible pour une personne qui traite le patient.

7. Equipement de surveillance selon la revendication 6, **caractérisé par** l'unité de mesure et par le dispositif de communication qui constituent un élément combiné, dans lequel la pile du téléphone mobile ou du récepteur de poche à deux voix et l'unité de mesure sont intégrées dans un seul composant (14') qui se monte dans le volume destiné à la pile du téléphone mobile ou du récepteur de poche à deux voix.

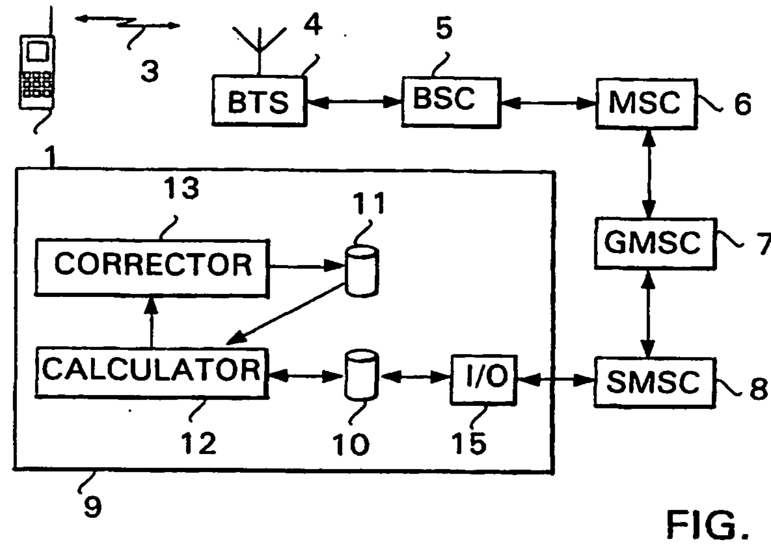

FIG. 1

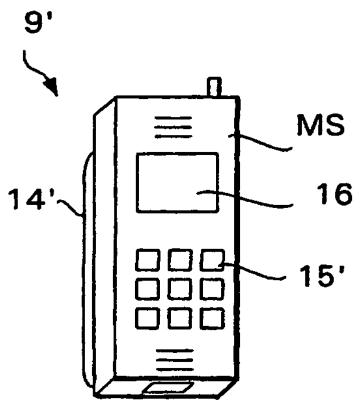

FIG. 2

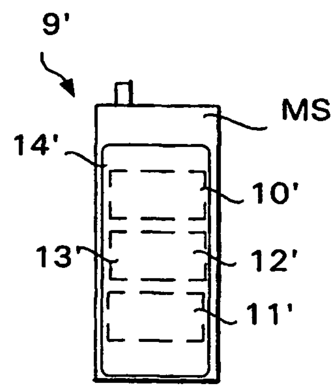

FIG. 3

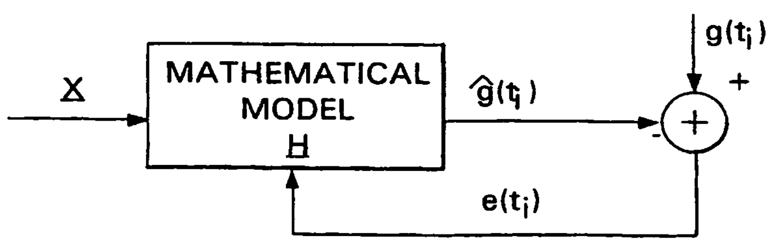

FIG. 4